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Inter-connection between land use/land cover change and herders'/farmers' livestock feed resource management strategies: a case study from three Ethiopian eco-environments

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ABSTRACT

We assessed land use/land cover changes from remotely sensed satellite imagery and compared this with community perceptions on availability/use of livestock feed resources and feed deficit management strategies since the 1973s in three districts representing the pastoral, agro-pastoral and mixed crop-livestock eco-environments of Ethiopia. We found that land use/land cover changes are proceeding in all eco-environments and that transitions are from grasslands, and forest lands to bush/shrub lands and crop lands in the pastoral site (Liben), from bush/shrub lands and grasslands to crop lands in agro-pastoral site (Mieso) and from bush/shrub lands, forest lands and grasslands to crop lands in the mixed crop-livestock site (Tiyo). The changes significantly affected livestock feed resources and feed deficit management strategies available to households. Over the last 30–40 years, grazing resources available to livestock keepers have been declining with resultant increase in the contribution of crop residues and other feeds from crop lands (weeds and crop thinnings) as compared to feeds from grasslands. The feed deficit management strategies of households are also changing significantly from mobility to herd management and feed conservation in the pastoral areas; from mobility to feed conservation and purchasing of feed in the agro-pastoral areas and from transhumance to feed conservation and purchase of feed in the mixed crop-livestock areas. Hence feed resources and their availability vary with time and eco-environments indicating the need for the development of eco-environment/site specific feed management strategies in order to support productive stock in the study areas and similar eco-environments.

1. Introduction

Ethiopia while located in the tropics has wide eco-environmental settings that range from arid and semiarid tropical lowlands to cool afro alpine highlands and mountains. The warm and drier lowlands in the south east, eastern and north eastern part of the country are constrained by low and erratic rainfall for reliable crop production and are thus used for extensive pastoral livestock production (Coppock, 1994). On the other hand, the highland plateau and mountains above 1500 m asl constitute less than 40% of the total land mass of the country and are under extensive mixed crop-livestock production. In between these two systems there are transitional areas known as agro-pastoral areas that share the properties of both pastoral and mixed crop-livestock systems.

Across these eco-environments, numerous studies have been carried out to identify land use/land cover changes in relation to drought vulnerability (Biazin and Sterk, 2013) and community perceptions (Oba and Kotile, 2001; Oba and Kaitira, 2006; Beyene, 2009; Garedew et al., 2009). Many of these studies, however, focused on analysis of drivers of the changes (Reid et al., 2000; Amsalu et al., 2007; Tsegaye et al., 2010; Meshesha et al., 2012; Biazin and Sterk, 2013), and only a few studies have dealt with

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consequences (Reid et al., 2000; Meshesha et al., 2012) and none have dealt with land use/land cover change in relation to availability and management of livestock feed resources.

Feed is an important component of livestock farming. The supply of feed both in quantity and quality determines productivity and profitability of farms (Sarwar et al., 2002). In Ethiopia, livestock feeds are derived mainly from annual foraging over large areas of grazing lands. Substantial amounts of feeds are also derived from crop residues, agro industrial by-products and other non-farm and farm products (Ibrahim, 1999; Habte, 2000; Mengistu, 2005; Tolera et al., 2012). The proportional contribution of these feed resources, however, is subject to variations in agro-ecosystem, farming system, and the type of animals reared (Aregheore, 2000; Rahman et al., 2008). Largely irreversible human activities over land surfaces including the clearing of forest, cultivation, overgrazing, settlements, industrialization, urbanization and other forms of land management (Meyer and Turner, 1992; Reid et al., 2000; McCusker, 2004; Luoga et al., 2005; VanWey et al., 2007; Garedew et al., 2009; Lambin and Meyfroid, 2011) are causing changes in land use and land cover patterns (Homewood et al., 2001; Feddema et al., 2005) with resultant change in livestock feed resource composition, feed deficits and feeding management strategies. Because of these dynamic changes, traditional feed resources, and existing feeding management strategies are no longer adequate to sustain a productive livestock population (Benin et al., 2002; Sarwar et al., 2002).

In many areas, the traditional rangeland-based nomadic pastoral systems where livelihoods are based on extensive movements over vast areas of land are under threat (Coppock, 1994; Bollig and Schulte, 1999; Gebru et al., 2003; Muller et al., 2007; Elias, 2008). Increased use of limited land for competing interests occasionally flares into conflicts among neighbors (Yemane, 2003; Beyene, 2009; Gizachew, 2012). As a result, as grazing resources decrease and the availability of by-products from farmland increase, changes are expected from grazing based feed deficit management strategies (mobility, transhumance, wet and dry season grazing) to non-grazing-based feed use and conservation strategies (purchase of feed, feeding of crop residues, use of agro industrial by-products) (Aerts et al., 2009; Dikshit and Birthal, 2010; Sarwar et al., 2002). In line with this, a study conducted in northern Ethiopia revealed that availability and use of communal grazing lands, private pastures, woodlots and forest areas as feed sources has significantly declined over the past decades and that this was mirrored by an increase in availability and use of crop residues and purchased feeds (Benin et al., 2002). Purchasing of feeds include agro-industrial by-products from market, crop residues, pastures and others from neighboring farmers who have no animals to feed or sales of feed to obtain cash for various purpose.

The inter-connections of changes in feed resource with land use/land cover change, however, is less understood. On the one hand, long-term monitoring of land use/land cover from remotely-sensed satellite imagery and GIS gives quantitative information on the surface coverage of different land use/land cover categories or classifications. Combining satellite and GIS based land use/land cover information with community observations and practices on the ground could give a fuller picture of the effects of land use/land cover changes on feed resource availability and herders' and farmers' practices of feed deficit management. Therefore, this paper firstly presents results of a land use/land cover monitoring exercise since the 1973s over three districts located in the three major eco-environments in Ethiopia. Secondly community perceptions on the relative availability of different feeds and feed deficit management strategies in response to changes in land use/land cover over the last 30–40 years were assessed. Thirdly we discussed implications of the temporal change in availability of different feeds and feed deficit management strategies on capacity of land to support productive stock.

2. Materials and methods

2.1. Description of the study areas

This study was carried out across three eco-environments in Ethiopia. These were the pastoral, agro-pastoral and the mixed crop-livestock systems. The pastoral eco-environment constitutes a significant part of the low lands below 1500 m asl. It covers extensive areas of, Oromia, Afar, Somali and the Southern Nations Nationalities and Peoples Region (SNNPR) regional states of the Federal Democratic Republic of Ethiopia. The pastoral eco-environment is not suitable for reliable rainfed crop production unless supplemented with irrigation (Coppock, 1994; Abebe, 2000; Desta, 2000). It is inhabited by about 12% of the human and 24% of the livestock populations of the country (TECHNIPLAN, 2004). The highlands - dissected by the Great Rift Valley into western and eastern highlands - constitute the central part of the country where precipitation is sufficient both in amount and distribution for good crop production. Thus the major land use in the highlands is extensive smallholder mixed crop-livestock production (Gebru, 2001). The highlands with less than 40% of the land mass of the country is populated by over 60% of the human and 70% of the livestock population of the country (Gebru, 2001). The agro-pastoral eco-environment on the other hand, is intermediate between the more livestock-based pastoral and the crop-dominated highland systems. It is fairly widely distributed in a number of Ethiopia's regional states without having the clear spatial coherence and boundaries characterizing the pastoral and mixed crop-livestock eco-environments.

From each of these eco-environments, one district typical of the respective eco-environment was randomly selected. Accordingly Liben, Mieso and Tiyo districts were selected from the pastoral, agro-pastoral and the mixed crop-livestock eco-environments, respectively.

Liben district is found in Guji Zone of the Oromia National Regional State to the south east of Addis Ababa (Fig. 1). The district's capital, Negele-Borana, is located at 610 km south of Addis Ababa. The district lies between 4º38′55″ and 5º33′7″ N latitude, and 39º9′25″ and 39º58′37″ E longitude. It has a semiarid climate with two wet and two dry seasons a year. The main rainy season lasts from March to May followed by a dry season in June, July and August and then by a small rainy season in September, October and November followed by another main dry season in December, January and February. It is sparsely populated with a typical pastoral livestock production system where herding is the main livelihood. The climatic conditions are summarized in Table 1.

Mieso district is found in the west Hararge Zone of the Oromia National Regional State in eastern Ethiopia within the Rift Valley system of the country (Fig. 1). The district's capital, also called Mieso is located 325 km to the east of Addis Ababa. The district is situated between 8°47′33″ and 9°19′15″ N latitude, and 40°9′20″ and 40°58′8″ E longitude. It has two rainy and one dry season in a year. The main rainy season lasts from June to September followed by dry harvesting season from October to January and the second small rainy season from February to May. It has a semiarid climate with highly erratic rainfall. Due to unreliable weather conditions, crop production is an opportunistic activity complementing livestock husbandry. Farmers in the district grow sorghum, maize and haricot bean as major crops. The climatic conditions are summarized in Table 1.

Tiyo district is located in Arsi Zone of the Oromia National Regional State. The district's capital, Asela, is located 175 km south

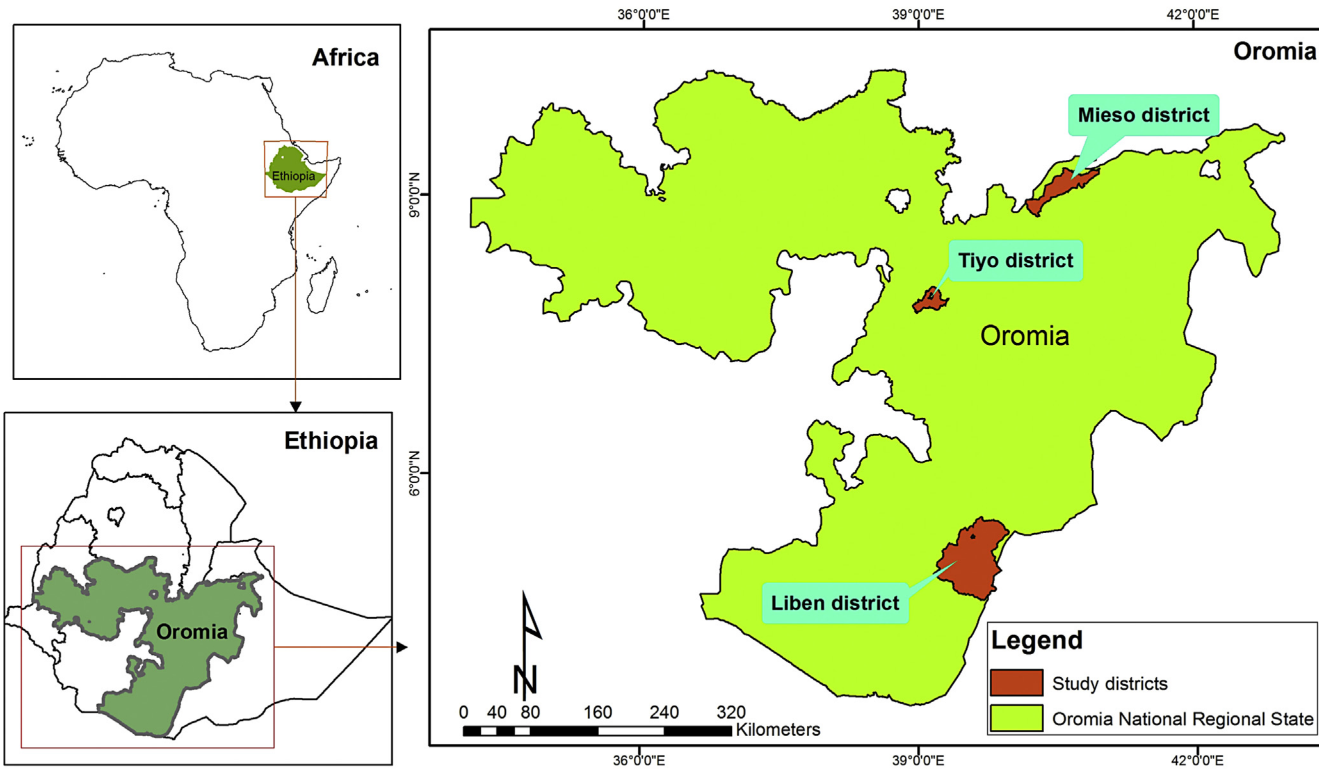

Fig. 1. Geographic location of study districts with respect to Oromia National Regional State in Ethiopia.

east of Addis Ababa (Fig. 1). The district is bound between 7°45′13″ and 8°2′26″ N latitude, and 38°56′6″ and 39°19′33″ E longitude. It has two rainy seasons and one dry period in a year. The main rainy season lasts from June to September followed by dry crop harvesting season from October to January and the second small rainy season from February to May. The district is subtropical highland in climate, densely populated and is known for production of cool season crops such as wheat, barley, faba bean and field peas. The climatic conditions are summarized in Table 1.

2.2. Satellite image interpretation

2.2.1. Data source and image pre-processing

For the purpose of this study, satellite images from different time periods were used for the interpretation of land use/cover in the three districts. The images were from 1973, 1986, 2000 and 2007 and were downloaded from the Global Land Cover Facilities web site (http://www.glcf.umd.edu/data/landsat; http://glovis.usgs.gov/). The satellite images from different periods have different spatial and radiometric resolution. The 1973 Landsat (Multispectral Scanner (MSS) images have a spatial resolution of 60 m while the 1986 Landsat Thematic Mapper (TM), 2000 and 2007 Landsat ETM (Enhanced Thematic Mapper) have a spatial resolution of 30 m (Table 2). The images from the four years were geometrically rectified1 and registered to a common projection using Universal Transverse Mercator (UTM), Clarke 1880 Spheroid, and Adindan Zone 37 North datum. For compatibility purposes all the TM and ETM images were resampled, using the nearest neighborhood technique, to the spatial resolution of MSS image. The 1973 images have four bands and the 1986, 2000 and 2007 images have 7 bands hence image stacking was carried out. District boundaries also cover more than one pane image hence image mosaicing was carried out between adjacent panes and subsequently image subsetting was conducted based on district boundaries.

2.2.2. Sampling design, image interpretation and accuracy assessment

For the purpose of this study stratified random sampling design was used. First district map was overlaid by high resolution Google Earth images (Spot 4 and 5 with spatial resolution of 10 and 2.5 m, respectively). The images were then classified into six land use/land cover classes following the classification used to develop the land

Table 1
Surface area, elevation and summary of climatic variables in the study districts computed from data provided by National Meteorological Agency of Ethiopia (NMA) for Negele-Borana, Mieso and Asela weather stations located in Liben, Mieso and Tiyo districts, respectively for the period 1967–2008.

Description	District		
	Liben	Mieso	Tiyo
Surface area of the district (km^2)	5057	1457	605
Elevation range in the district (mamsl)	614–1639	823–2475	1653–3855
Mean annual rainfall (mm)	762.4	793.9	1149.0
Mean annual minimum temperature range (°C)*	10.0–19.5	4.2–21.6	4.9–10.3
Mean annual maximum temperature range (°C)*	18.4–31.4	21.6–37.1	18.3–24
Annual rainfall trend (mm/decade)**	+7.7	+1.9	+6.0
Mean annual temperature trend (°C/decade)**	+0.64	+0.13	+0.67

* The minimum and maximum mean annual temperatures recorded during 1967–12008; ** is the increasing (+) or decreasing (−) annual trend during 1967–2008.

Table 2
Type of Land sat mapper, spatial resolution and Image acquisition date.

Location	Path	Row	Type of Mapper	Resolution (m)	Acquisition date
Mieso	180	054	MSS	60	30 January, 1973
	179	054	MSS	60	12 December, 1973
	167	054	TM	30	30 January, 1986
	167	054	ETM	30	28 November,2000
	167	054	ETM	30	18 December, 2007
Tiyo	180	055	MSS	60	30 January,1973
	168	054	TM	30	21 January, 1986
	168	055	TM	30	21 January, 1986
	168	054	ETM	30	05 December, 2000
	168	055	ETM	30	26 February, 2000
	168	054	ETM	30	09 December, 2007
	168	055	ETM	30	26 January, 2007
Liben	180	057	MSS	60	30 January, 1973
	180	056	MSS	60	30 January 1973
	179	057	MSS	60	29 January 1973
	179	056	TM	30	30 November, 1975
	167	057	TM	30	14 January, 1986
	167	056	TM	30	16 December, 1986
	168	056	TM	30	21 January, 1986
	167	057	ETM	30	31 January, 2000
	167	056	ETM	30	28 December, 2000
	168	056	ETM	30	05 February, 2000
	167	057	ETM	30	05 March, 2007
	167	056	ETM	30	05 March, 2007
	168	056	ETM	30	07 January, 2007

ETM = Enhanced Thematic Mapper, MSS = Multispectral Scanner, TM = Thematic Mapper.

Table 3
Land use/land cover description in the three study eco-environments.

Ser. no.	LULC types	Description
1	Bare land	Rock outcrop with or without vegetation coverage <4%, coarse fragments/bare soil/loose and shifting sands, eroded lands, water bodies. No feed is expected to be available
2	Bush land	Open trees with open shrubs and open herbaceous, closed to open medium to high shrub land, closed to open medium tall herbaceous vegetation with low trees and shrub. The expected feed type is bush/shrub land grazing
3	Crop land	Rain fed herbaceous crop fields, surface irrigation herbaceous crop fields, herbaceous small fields with sparse trees. Expected feed type is crop residue and aftermath grazing
4	Forest land	Forest plantation or forestation, closed trees (dense forest) with a closed cover >65%. The expected feed type is litter and under forest grazing
5	Grass land	Herbaceous closed to open medium tall vegetation (closed to open grass land). The expected feed type is open grazing
6	Settlement	Urban areas, any type of vegetated areas inside the urban areas, and rural villages, built up lands, roads. The expected feed type is food and beverage processing by-products usable as feed.

cover map of Africa (Mayaux et al., 2004) with minor modification made to address the objectives of the present study (Table 3). The land use/land cover classes were then divided into 60 × 60 m pixels, and 300 sampling points (identified good enough to represent the study area after iteratively trying 250, 300 and 350 sampling points) were divided among the six land use/land cover classes proportional to its area (Table 4), and randomly assigned to the 60 × 60 m pixels. The random seeded sampling points were then given independent identification numbers from 001 to 300.

For change analysis, according to Loveland et al. (2002) the traditional automated to semi-automated change detection techniques which are based on spectral change information alone do not consider important change detection such as texture, shape, size and patterns. However, these components can be incorporated by a skilled analyst making visual interpretations of imagery (Loveland et al., 2002). Hence instead of the classical resource and time extensive boundary based segmentation strategy commonly in use in the classical automatic classification schemes, we used an object

Table 4
Area coverage and number of sampling points proportionally allocated to each land use/land cover classes.

	Area (km^2)*			# of allocated sampling points		
Land use/land cover class	Liben	Mieso	Tiyo	Liben	Mieso	Tiyo
Bare land (BRL)	252.8	34.0	6.1	15	7	3
Bush land (BUL)	3270.2	816.0	68.6	194	168	34
Crop land (CRL)	556.3	306.0	409.6	33	63	203
Forest land (FOL)	67.4	29.0	54.5	4	6	27
Grass land (GRL)	741.7	238.0	38.0	44	49	19
Settlement (ST)	168.6	34.0	28.3	10	7	14
Total	5057.0	1457.0	605.1	300	300	300

* Source: district offices of Agriculture.

Table 5
Accuracy assessments of classified image in to different land use/land cover classes (comparing classification 2007 and Google earth images).

Land-use/land cover class	Accuracy %					
	Liben		Mieso		Tiyo	
	Producer's	User's	Producer's	User's	Producer's	User's
Bare land (BRL)	66.67%	76.92%	57.14%	80.00%	66.67%	100.00%
Bush land (BUL)	98.45%	96.95%	95.24%	95.81%	58.82%	74.07%
Crop land (CRL)	81.82%	81.82%	90.48%	79.17%	98.52%	91.32%
Forest land (FOL)	75.00%	60.00%	66.67%	100.00%	62.96%	62.96%
Grass land (GRL)	79.55%	85.37%	77.55%	80.85%	52.63%	71.43%
Settlement (ST)	90.00%	81.82%	71.43%	100.00%	64.29%	81.82%
Over all accuracy	91.67%		89.33%		86.00%	
Kappa coefficient	0.86		0.83		0.71	

based segmentation strategy (Loveland et al., 2002; Plourde and Congalton, 2003) in which point level on screen visual observation, classification of observations and manual coding of the classified observations were made on the randomly seeded observational points. The tagged sampling points were used as fixed reference points and the land user/land cover to which they refer was visually observed and classified into one of the land use/cover classes. The process of visual observation and interpretation was carried out beginning with the Google Earth images (which served as land cover baseline template) and then switching backward to classify images of the 2007, 2000, 1986 and 1973 displayed by different windows.

Accuracy assessment was carried out on data of 2007 images by comparing with pseudo-ground-truthed data from the high resolution (2.5 × 2.5 m for SPOT5 and 10 × 10 m for SPOT4) Google Earth image. Error matrices that describe the patterns of mapped class relative to the reference data were generated, from which the overall accuracies, user's and producer's accuracies, and Kappa statistics were derived to assess the accuracies of the classification maps (Table 5).

The land use/land cover output of the four periods were converted to dbf format and imported to Microsoft excel for further processing. The data were presented as percentage of the different land use/land cover classes and change detection matrix was derived to identify land use/land cover transitions between 1973 and 2007 (see attached material for details).

2.3. Household survey

2.3.1. Questionnaire preparation

Following the satellite image interpretation, a human centered survey was conducted in the three districts to understand the effect of the observed land use/land cover change on availability of feeds and feed deficit management strategies. Following initial level literature search and discussions with experts, check lists were prepared and used in group discussions with herders and farmers to elicit information on changes in availability and use of various feeds and management strategies over the last 30–40 years. Based on feedback, semi-structured questionnaires were prepared and tested with 10 randomly selected herders and farmers from each site. Questionnaires were then further refined and fully structured for the final interview.

2.3.2. Sample size determination

The 'kebeles' (the smallest administrative units below district) at the three districts were classified into three strata based on relative similarities in land use, agro-ecology and farming system with the help of district level experts. From each stratum one kebele was randomly selected and a household census was conducted to gather information on household size, age and location ('got') with the help of development workers at each kebele. Got is a cluster of houses in a given area within a kebele; sometimes it is synonymous with village. Household heads above 50 years old (assumed to have rich local knowledge) were identified as the study population and each was assigned a serial number which was later used for random selection of the interview households from each village/got. From a total of 1669 households across the study areas, 217 households with household heads above 50 years were selected for interview (Bartlett et al., 2001). The numbers of respondents per site were designed to be proportional to the overall population in each site (81, 44 and 92 from Liben, Mieso and Tiyo, respectively).

2.3.3. Household interview

The interviews were conducted either in houses of the respondent, at public meeting places, at livestock watering points or occasionally in other places. In case a household head could not be reached for various reasons or where they refused to be interviewed or had left the village for a time longer than the survey period, a replacement was selected by randomly selecting from the list of households in the same village/got. During the interview, each respondent was provided with 100 maize seeds to share among different response options to show relative contribution of each feed type or management strategy to the total amount of feed or management strategies available to him/her both at present and 30–40 years ago. This was done for the major rainy, small rainy and dry seasons separately and later average values were taken for the analysis. The time taken to interview a respondent was recorded and found to vary from 1:00 to 1:30 h.

2.4. Data analysis

The data on households' response on relative contribution of each feed type (grazing, crop residue, agro industrial by-product, cultivated forage crops and other feeds from croplands), and the feed deficit management strategies (mobility, transhumance, feed conservation, herd management, purchase of feed and other supplementations) were subjected to a paired *T* test analysis to compare mean differences between past (30–40 years ago) and present (2011) conditions using SPSS for each site separately. Paired *T* test is chosen to be appropriate since the two sets of data to be compared are taken from same household heads and are thus paired. Significant differences were tested at 5% probability levels.

3. Results

3.1. Land use/land cover change for the period 1973–2007

The dominant LULC type at Liben district is bush/shrub lands followed by grasslands (Fig. 2). However, changes have occurred in land use/land cover over the study

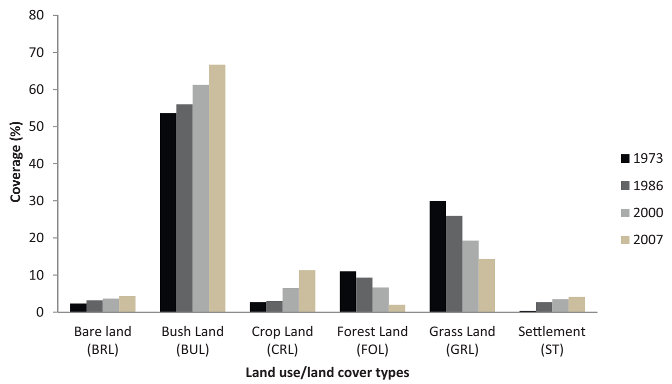

Fig. 2. Land use/land cover changes in Liben district over the period 1973 and 2007.

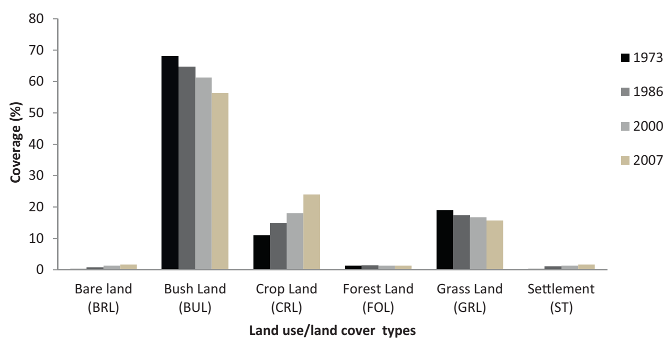

Fig. 3. Land use/land cover changes in Mieso district over the period 1973 and 2007.

period. During the study period the area under bush/shrub land, bare land, crop land and settlements have shown positive changes. Between 1973 and 2007 bush/shrub land expanded most by 12% followed by cropland which has increased by 8.3% with rapid expansion since 1986. The areas under settlement and bare lands have shown the least increase at 3.3 and 2.0% respectively. On the other hand, the area under grass land and forest land decreased by 16.3 and 9.3%, respectively. This indicates that bush/shrub land is the major source of livestock feed as the availability and use of grasslands and forest lands as feed sources have declined over the last decade. There has also been an increase in the area of crop lands along with bush/shrub lands and presumably an accompanying increase in livestock feed derived from crop sources.

Similar to Liben district, the landscape at Mieso has been dominated by bush/shrub coverage (Fig. 3). Over the study period, however, crop land has expanded by 13.0%. Settlement and bare lands have also shown positive change each by 1.3%. On the other hand, the area under bush/shrub land and grasslands retracted by 12.3 and 3.3%, respectively. The area under forest coverage is small (1.3%) and remained almost unchanged over the study period. Similar to the results in Liben district, bush/shrub land is found to be the major source of feed in Mieso district. However, the availability and use of bush/shrub land and grasslands as feed sources have declined over the last decade leading to an increase in availability and use of feeds from crop lands.

Unlike the situation in the pastoral and agro-pastoral districts, the landscape in Tiyo district has been dominated by crops (Fig. 4). The area under crop land has expanded by 21.3%, whereas the area under settlements and bare lands increased by 3.0 and 0.4%, respectively. On the other hand, bush/shrub land, forest and grasslands have decreased throughout the study period. The area under grasslands contracted greatly by 15.0%. Bush lands and forest lands have decreased by 7.0 and 2.7%, respectively. The results in general indicate that crop land has become the major source of feed in Tiyo district while there has been a rapid decline of feeds from bush/shrub land, forestland and grasslands.

3.2. Effect of land use/land cover change on availability of feeds

As shown in Table 6, the available feeds identified during discussion with household heads include grazing, crop residues, agro-industrial by-products, cultivated forage crops and other categories of feeds from crop lands. The relative contribution of these different categories of feed resources, however, differed between past (30–40 years ago) and present conditions with a significant difference between the two periods. In the past, grazing was the most available feed for households accounting for 100% of the total feeds available to households in Liben, 95.0% in Mieso and 70.0% in Tiyo. However, the contribution of feed from grazing has significantly

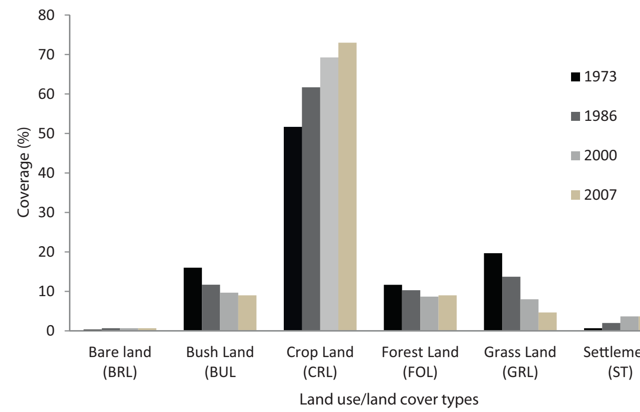

Fig. 4. Land use/land cover changes in Tiyo district over the period 1973 and.

decreased over the last 30–40 years by about 16.0% in Liben, 67.0% in Mieso and 54.0% in Tiyo. On the other hand, the contribution of crop residues and other feeds from crop lands have significantly increased and become the major feed available to the households at present in Mieso and Tiyo. The contribution of crop residues increased from nil to 9.4% in Liben, by 33.0% in Mieso and by 27.0% in Tiyo. Similarly, the contribution of other feeds from crop lands increased by 6.6, 32.0 and 7.4% in Liben, Mieso and Tiyo districts, respectively. The use of agro industrial by-products has also significantly increased over the past 30–40 years in Liben and Tiyo. In Liben it increased from nil to 5.0% and in Tiyo from 6.2 to 10.7%. This shows that grazing resources have been diminishing over the years with conversion of large areas of grazing resources such as bush/shrub lands, forestlands and grasslands to croplands. As a result, availability of feeds from crop lands such as crop residues and others such as weeds and thinnings have increased in importance as feeds available to the households (Table 6).

3.3. Effect on feed deficit management strategies

During group discussion, herders and farmers identified a list of management strategies employed to overcome seasonal and long term shortages of feed (Table 7). These include mobility where herds are continually moved in search of pasture; transhumance ('godantu') where the entire herd or selected animals are seasonally sent with an attendant to a specified grazing area for a short period of time; feed conservation where feeds are reserved or conserved for use during certain periods of the year; herd management/destocking where certain animals are removed from the herd and or the type of animal changed; purchase of feed where a certain feed type is purchased from market or neighboring farmers. As was the case for feed availability and use, the contribution of these different categories of feed deficit management strategies differed across location and time.

In Liben district, salt supplementation and mobility were the major strategies, followed by feed conservation and herd management both in the past and present times. However, the contribution of mobility as a coping strategy significantly decreased by 8.8% over the last 30–40 years. On the other hand, there has been a significant increase in the purchase of feed by 1.2%, herd management by 7.4% and feed conservation by 3.3% in the same district (Table 7).

In Mieso, mobility was the major strategy 30–40 years ago accounting for 70% of all the feed deficit management strategies available to the households followed by transhumance (18.6%) and feed conservation (6.8%). Over the years, however, the use of mobility as a strategy has significantly decreased by 58.5%. Presently, feed conservation (64.5%) followed by transhumance (15.6%) and mobility (12.0%) have become the major strategies used by households in the district. Over the last 30–40 years, feed conservation and purchase of feeds significantly increased by 57.7 and 6.3%, respectively (Table 7).

In Tiyo district, feed conservation was the major strategy used by the household, both in the past and present. Over the years, the use of conserved feed and purchase of feeds has significantly increased by 7.0 and by 2.5%, respectively. On the other hand, the use of transhumance and mobility as strategies significantly decreased by 14.9 and by 2.6%, respectively (Table 7).

4. Discussion

4.1. Land use/land cover change

During the 34 year study period (1973–2007) the three study sites have experienced persistent land use/land cover changes as in many parts of the country (Reid et al., 2000; Mesele et al., 2006;

Table 6
Types of available feed resources and relative contribution of each to the total feed resource available to households 30–40 years ago and at present time (2011) in Liben, Mieso and Tiyo districts in Ethiopia as reported by respondents.

Type of feed resource	Liben			Mieso			Tiyo		
	30–40 years ago	Present (2011)	Significance	30–40 years ago	Present (2011)	Significance	30–40 years ago	Present (2011)	Significance
Grazing	100	83.7	*	94.7	31.4	*	69.7	32.4	*
Crop residue	0	9.4	*	5.0	37.9	*	19.1	48.6	*
Agro industrial by-products	0	0.3	*	0	0		6.2	10.77	*
Cultivated forage crops	0	0.1	ns	0	0		0.6	0.9	ns
Other feeds from crop lands (weeds, thinnings)	0	6.6	*	1.3	31.6	*	5.1	8.0	*
Total	100	100		100	100		100	100	

Note: values are means of $n = 81$ for Liben; $n = 44$ for Mieso and $n = 92$ for Tiyo.
*Significant at 5% probability level; ns = non-significant 5% probability level.

Amsalu et al., 2007; Tsegaye et al., 2010; Meshesha et al., 2012; Biazin and Sterk, 2013) and the rest of the sub-Saharan Africa region (Petit et al., 2001; Serneels et al., 2004; Mengistu and Salami, 2007; Baldyga et al., 2007; Kiage et al., 2007). Among the studied major land use/land cover categories, crop lands have generally increased throughout the period complementing global reports (Goldewijk and Ramankutty, 2004) while those of grasslands and forest lands have decreased. On the other hand, the area under bush/shrub lands has increased in Liben and decreased in Mieso and Tiyo. These changes could be related to biophysical and socioeconomic dynamics at local, national, regional and/or global level. Social factors such as human and livestock population pressure, land tenure arrangements and poverty and natural conditions such as climate are common causes of land use/land cover changes (Mengistu and Salami, 2007; Zak et al., 2008; Tsegaye et al., 2010; Meshesha et al., 2012; Biazin and Sterk, 2013).

In the past three decades, both the mixed crop-livestock and pastoral and agro-pastoral eco-environments experienced rapid increase in human population with concomitant need for subsistence crop and livestock production systems (Thornton, 2010; Tolera et al., 2012). As a result forest lands, bush/shrub lands and grasslands are increasingly brought under heavy pressure to feed the ever increasing human population (Garedew et al., 2009; Biazin and Sterk, 2013) and the remaining grazing lands are subject to over stocking (Tessema et al., 2011).The net effect of these changes is land degradation and increased coverage of bare lands. Due to repeated cycles of drought and famine episodes (Udessa, 2001; Desta and Coppock, 2004; NMA, 2007), herders and farmers are forced to adopt new systems of livelihood diversification based on unreliable crop cultivation (in pastoral areas) and clearing of woody vegetation for charcoal and lumber making and wood logs to sell in urban areas and for home use (Garedew et al., 2009; Tsegaye et al., 2010).

At the same time use of fire to clear vegetation was banned by government in the 1970s which led to encroachment of undesirable bushes and shrubs on the rangelands at the expense of grasslands (Angassa and Oba, 2008; Mesele et al., 2006; Haile et al., 2010) contributing to the observed increase in bush/shrub land in Liben. The different land tenure systems adopted by successive governments in Ethiopia and lack of policy and regulation enforcements during transition times also aggravated land use/land cover changes (Beyene, 2009; Meshesha et al., 2012; Rashid and Negassa, 2012; Biazin and Sterk, 2013) in the study areas.

4.2. *Effect of land use/land cover change on availability of feeds to households*

The perceived decline in contribution of grazing to the total feed available to the households is in line with the observed decrease in areas of bush/shrub land, grasslands and forestlands among the mixed crop-livestock (Tiyo) and agro-pastoral (Mieso) districts, but in contradiction with the observed increasing bush/shrub land coverage in the pastoral (Liben) district. This could be because of increase in density and area coverage of thorny bush and shrubs that makes the land inaccessible to grazing stock (Angassa and Oba, 2008), less grazing land productivity due to competitive decrease in population of the most palatable grass species and conversion of productive grazing lands to crop lands (Oba and Kotile, 2001; Abebe et al., 2012).

As grazing resources are progressively transformed into crop land, feeds of crop land products and/or by-products become major feed resources available to households in the mixed crop-livestock (Tiyo) and in agro-pastoral (Mieso) areas. Moreover, since crop residues are available only after harvest, farmers are increasingly relying on feeds from maize and sorghum fields (major crops of agro-pastoral areas) sown at high population density through

Table 7
Types of available feed deficit management strategies and relative contribution of each strategy to the total coping strategies available to households 30–40 years ago and at present time (2011) in Liben, Mieso and Tiyo districts in Ethiopia as reported by respondents.

Type of feed deficit management strategy	Liben			Mieso			Tiyo		
	30–40 years ago	Present (2011)	Significance	30–40 years ago	Present (2011)	Significance	30–40 years ago	Present (2011)	Significance
Mobility (nomadism)	34.0	25.2	*	70.5	12.0	*	2.6	0.1	*
Transhumance ('godantu')	10.7	10.4	ns	18.6	15.6	ns	15.1	0.2	*
Feed conservation	13.9	17.2	*	6.8	64.5	*	65.8	72.8	*
Herd management/destocking/	11.2	18.6	*	3.3	0.9	ns	6.9	6.5	ns
Purchase of feed	0.3	1.5	*	1.2	7.5	*	1.7	4.2	*
Other supplementations (salt, grain)	29.9	28.8	ns	0.5	0.5	ns	7.9	6.8	ns
Total	100	100		100	100		100	100	

Note values are means of $n = 81$ for Liben; $n = 44$ for Mieso and $n = 92$ for Tiyo.
*Significant at 5% probability level; ns = non-significant 5% probability level.

thinning, leaf stripping and weeding (Gebremedhin et al., 2007; Tolera et al., 2012). Presently these feed resources have become as important as grazing resources in Mieso district. On the other hand, the contribution of these feed resources at present is low in Liben although it is expected to increase with expansion of crop lands in the near future. Areas of crop production are expected to increase substantially over the coming years in all pastoral areas of the country due to the government's plan to sedentarize pastoralists with the provision of improved drought tolerant crop varieties, irrigation facilities and crop management options (Government of Ethiopia, 2001).

The availability and use of agro-industrial by-products depend on availability of food and/or beverage processing plants near to the study sites (Aregheore, 2000; Tolera et al., 2012). In Tiyo district, farmers have long had access to several small to medium scale oil and flour processing plants. In the pastoral and agro-pastoral districts, farmers and pastoralists have been exposed to the use of agro-industrial by-products through emergency relief aid (Gizachew, 2012) although availability is limited. Similarly efforts have been under way to promote forage crops cultivation in all eco-environments (Assefa, 2012) although the contribution of such crops to the total feed availability of households is small (Tefera et al., 2010) and has not changed over the last 30–40 years in any of the study sites.

4.3. Effect of land use/land cover change on feed deficit management strategies of the households

In the past mobility was a major means of overcoming shortages of feed in the pastoral (Liben) and agro-pastoral (Mieso) areas because of free access to large tracts of land. The observed decline in grazing resources at all sites coupled with land fragmentation due to increased crop encroachment (Desta, 2000; Reid et al., 2004), privatization of communal grazing lands and fencing of the most important grazing lands (Angassa and Oba, 2008; Napier and Desta, 2011), increase in bush density in Liben (Angassa and Oba, 2008) and inter-and intra-ethnic conflicts in Mieso and Liben (Beyene, 2009; Udessa, 2001) has reduced land area available for the free movement of livestock. Moreover, repeated loss of animals to droughts and the decline in per capita livestock holdings has weakened many households (Udessa, 2001; Desta and Coppock, 2004) and reduced the need for pastoral mobility among many pastoral households. Likewise the contribution of transhumant movements of the herd as a means to overcome seasonal shortage of feed in mixed crop-livestock (Tiyo) has significantly declined due to expansion of large scale commercial crop farms in the 1970s and 1980s and subsequent conversion to arable production of forest and bush/shrub land areas to which farmers used to move their herds (Clapham, 1988; Macharia and Ekaya, 2005).

On the other hand, the contribution of feed conservation strategies has increased over the last 30–40 years. Such strategies include heaping of crop residues instead of burning on threshing fields among mixed crop-livestock keepers and agro-pastoralists; standing hay preparation through fencing of grazing land for private, semiprivate and communal use instead of the traditional wet and dry season communal grazing in the pastoral and agro-pastoral areas (Scoones, 1991; Coppock, 1994; Angassa and Oba, 2008); purchase of agro-industrial by-products from nearby markets, use of neighbors crop residues and plots of grazing lands when neighbors have few or no animals. Herd management through changing the type of animals kept from cattle to camels and poultry is also common among the pastoralists (Desta and Coppock, 2004; Abebe et al., 2012).

4.4. Implications of the changes in feed resources and management to support productive stock

Many studies have shown the wide gap between current available livestock feed and demand for such feed (Benin et al., 2002; Sarwar et al., 2002; TECHNIPLAN, 2004; Berhe et al., 2013). Land use/land cover change induced transitions from grazing to non-grazing based feed resources have led to increasing feed shortages. Crop residues which now account for over 50% of the feed resources of the country are low in nutritional value (Habte, 2000), and a substantial proportion is lost to spoilage during both storage and use (Tolera et al., 2012). The energy-and protein-rich agro-industrial by-products often in use to enhance nutritional values of crop residues are also constrained by limited availability and unaffordable prices due to export of oil seed crops (Tolera et al., 2012).

Moreover, the use of high yielding crop varieties with high nutrient requirement (Gebremedhin et al., 2007); increased removal of crop residues; increased stall feeding and back yard disposal of excreta (Haileslassie, 2007) or use of dung for fuel (Amsalu et al., 2007) are increasingly removing nutrients from farm lands. These accompanied with low rates of external fertilizer application (Spielman et al., 2012) disrupt nutrient cycling in cultivated lands and have led to a decline in long term productivity of land (Braimoh and Vlek, 2004; Schlecht et al., 2004; Biro et al., 2013).

In the pastoral areas around Liben, crop cultivation and rangeland fencing have become widespread since the 1983–85 droughts to deal with human food gaps created by massive cattle mortality (Angassa and Oba, 2008; Desta and Coppock, 2004; Tache and Oba, 2010). The expansion of crop cultivation and private and semiprivate fencing into the prime grazing rangelands, however, is perceived as a serious threat to livestock production and traditional resource management practices (Reid et al., 2004; Solomon and Snyman, 2007; Tache and Oba, 2010) because of crop failure due to unreliable rainfall (Angassa and Oba, 2008). Successful crop harvests in the pastoral areas are possible only once in every three years or so (Desta and Coppock, 2004) and the productivity is only 31% of the average national grain yield of Ethiopia (Tache and Oba, 2010). Such frequent crop failures and low productivity result in less crop residues and increased removal of valuable grass species from the land. Private or semiprivate grazing land fencing reduces free movements of livestock, limits access to other communities and increases over stocking on remaining communal lands (Angassa and Oba, 2008; Napier and Desta, 2011). This ultimately results in severe overgrazing, declining livestock productivity and greater vulnerability to drought.

The results imply the need for appropriate policy and development measures for planned and regulated land use management. Further measures such as population growth regulation, keeping fewer improved productive livestock, technical interventions to improve the nutritive value of crop residues, increasing domestic processing and availability of by-products, minimizing feed losses and improving the efficiency of various feed conservation strategies could have potential positive effect on feed availability.

5. Conclusions

From the results of the present study, it is clear that land use/land cover changes are occurring in all eco-environments of Ethiopia. The changes in land use/land cover have significantly affected feed resource availability and the feed deficit management strategies of households in the study areas. The transitions in the type of the available feeds from grazing to non-grazing (crop residues, agro-industrial by-products, weeds and thinnings) resources, and the feed deficit management strategies from mobility and transhumance to feed conservation and purchase of feeds have not been able to meet growing feed demands of households in many of Ethiopians major eco-environments. Among contributing factors are low productivity of fragmented land, low availability and quality of feed and feed losses at storage and use. The results suggest the need for land use based on its capability; improving the quantity and quality of available feeds, improving the genetic makeup of animals toward efficient use of available feeds and high productivity, providing alternative means of traction as well as improving the efficiency of site-specific feed conservation strategies through research and development interventions in order to support productive stock in the respective eco-environments.

Conflict of interest statement

As main and corresponding author representing others, I wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. I confirm that the manuscript has been read and approved by all authors and that there are no other persons who satisfied the criteria for authorship. I further confirm that the order of authors listed in the manuscript has been approved by all authors. I confirm that we have given due consideration to the protection of intellectual property and regulations of our institutions associated with this work and that there are no impediments to publication, including the timing of publication. All authors understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. I confirm that we have provided a current, correct email address which is accessible by me, the Corresponding Author, and which has been Configured to accept email from (mekashaaklilu@gmail.com).

Regards,

Aklilu Mekasha

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Appendix A.

Fig. A1.
Fig. B2.
Fig. C3.
Table A1.
Table B2.
Table C3.

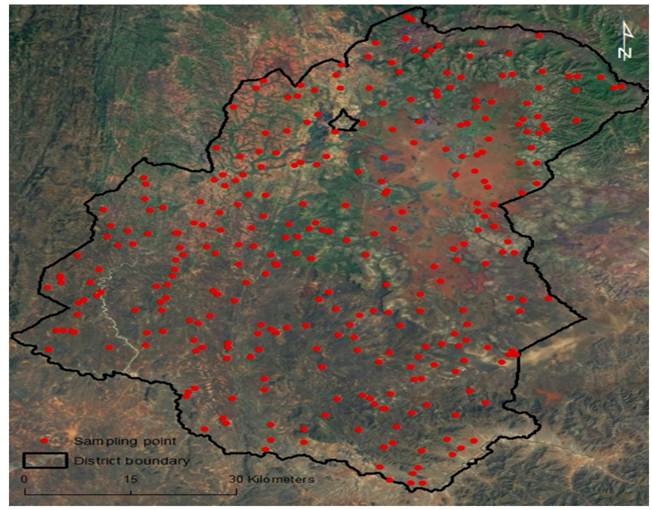

Fig. A1. Map showing location of sampling points randomly seeded on recent Google Earth image in Liben district, Ethiopia.

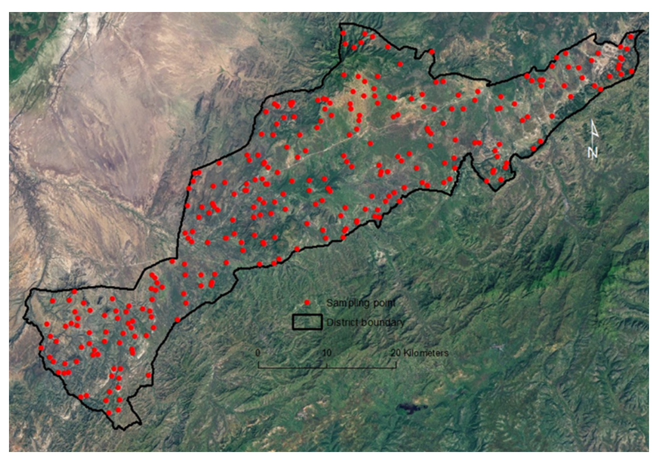

Fig. B2. Map showing location of sampling points randomly seeded on recent Google Earth image in Mieso district, Ethiopia.

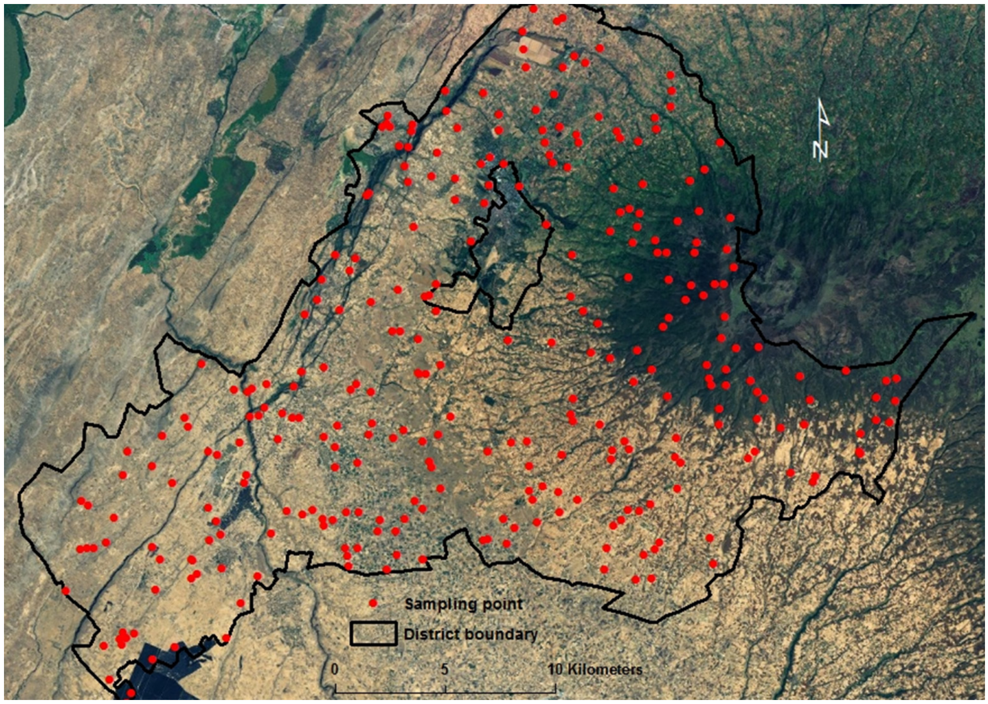

Fig. C3. Map showing location of sampling points randomly seeded on recent Google Earth image in Tiyo district, Ethiopia.

Table A1
Land use/land cover transition matrix showing percentage changes between 1973 and 2007 at Liben district, Ethiopia.

	Land use/ land cover class	Year 2007 Bare land (BRL)	Bush Land (BUL)	Crop Land (CRL)	Forest Land (FOL)	Grass Land (GRL)	Settlement (ST)	Total 1973[b]	loss 1973[d]
Year 1973	Bare land (BRL)	1.33[a]	1.00	0.00	0.00	0.00	0.00	2.33	1.00
	Bush Land (BUL)	0.00	43.67[a]	1.67	0.33	6.00	2.00	53.67	10.00
	Crop Land (CRL)	0.33	0.67	1.67[a]	0.00	0.00	0.00	2.67	1.00
	Forest Land (FOL)	0.67	5.67	3.00	1.00[a]	0.33	0.33	11.00	10.00
	Grass Land (GRL)	2.00	14.67	4.67	0.33	7.33[a]	1.00	30.00	22.67
	Settlement (ST)	0.00	0.00	0.00	0.00	0.00	0.33[a]	0.33	0.00
	Total 2007[c]	4.33	65.68	11.01	1.66	13.66	3.66	100.00	
	Gain 2007[e]	3.00	22.01	9.34	0.66	6.33	3.33		
	Net change [f]	2.00	12.01	8.34	−9.34	−16.34	3.33		
	Net persistence (ratio)[g]	1.50	0.28	4.99	−9.34	−2.23	10.09		55.33[h]

[a] Percentage of land for each class that did not show change between 1973 and 2007.
[b] Is the sum of figure in the row.
[c] Is sum of figure in the column.
[d] Is *b* minus *a*.
[e] Is *c* minus *a*.
[f] Is *e* minus *d*.
[g] Is ratio of *f* to *a* (*f*/*a*).
[h] Is the percentage sum of land use/land covers that has not undergone changes between 1973 and 2007.

Table B2
Land use/land cover transition matrix showing percentage changes between 1973 and 2007 at Mieso district, Ethiopia.

	Land use/land cover class	Year 2007 Bare Land (BRL)	Bush Land (BUL)	Crop Land (CRL)	Forest Land (FOL)	Grass Land (GRL)	Settlement (ST)	Total 1973[b]	loss 1973[d]
Year 1973	Bare land (BRL)	0.33[a]	0.00	0.00	0.00	0.00	0.00	0.33	0.00
	Bush Land (BUL)	0.67	48.33[a]	14.33	0.33	3.67	0.67	68.00	19.67
	Crop Land (CRL)	0.33	6.67	3.33[a]	0.00	0.33	0.33	10.99	7.66
	Forest Land (FOL)	0.00	0.00	0.33	0.33[a]	0.67	0.00	1.33	1.00
	Grass Land (GRL)	0.33	0.67	6.00	0.67	11.00[a]	0.33	19.00	8.00
	Settlement (ST)	0.00	0.00	0.00	0.00	0.00	0.33[a]	0.33	0.00
	Total 2007 [c]	1.66	55.67	23.99	1.33	15.67	1.66	100.00	
	Gain 2007 [e]	1.33	7.34	20.66	1.00	4.67	1.33		
	Net change [f]	1.33	−12.33	13.00	0.00	−3.33	1.33		
	Net persistence (ratio) [g]	4.03	−0.26	3.90	0.00	−0.30	4.03		63.65[h]

[a] Percentage of land for each class that did not show change between 1973 and 2007.
[b] Is the sum of figure in the row.
[c] Is sum of figure in the column.
[d] Is *b* minus *a*.
[e] Is *c* minus *a*.
[f] Is *e* minus *d*.
[g] Is ratio of *f* to *a* (*f*/*a*).
[h] Is the percentage sum of land use/land covers that has not undergone changes between 1973 and 2007.

Table C3
Land use/land cover transition matrix showing percentage changes between 1973 and 2007 at Tiyo district, Ethiopia.

	Year 2007 Land use/land cover class	Bare Land (BRL)	Bush Land (BUL)	Crop Land (CRL)	Forest Land (FOL)	Grass Land (GRL)	Settlement (ST)	Total 1973[b]	Loss 1973[d]
Year 1973	Bare land (BRL)	0.33[a]	0.00	0.00	0.00	0.00	0.00	0.33	0.00
	Bush Land (BUL)	0.33	9.00[a]	5.00	0.67	0.00	1.00	16.00	7.00
	Crop Land (CRL)	0.00	0.00	50.00[a]	0.00	0.33	1.33	51.66	1.66
	Forest Land (FOL)	0.00	0.00	7.67	3.33[a]	0.00	0.67	11.67	8.34
	Grass Land (GRL)	0.00	0.00	10.00	5.00	4.33[a]	0.33	19.66	15.33
	Settlement (ST)	0.00	0.00	0.33	0.00	0.00	0.33[a]	0.66	0.33
	Total 2007[c]	0.66	9.00	73.00	9.00	4.66	3.66	100.00	
	Gain 2007[e]	0.33	0.00	23.00	5.67	0.33	3.33		
	Net change [f]	0.33	−7.00	21.34	−2.67	−15.00	3.00		
	Net persistence (ratio) [g]	1.00	−0.78	0.43	−0.80	−3.46	9.09		67.32[h]

[a] Percentage of land for each class that did not show change between 1973 and 2007.
[b] Is the sum of figure in the row.
[c] Is sum of figure in the column.
[d] Is *b* minus *a*.
[e] Is *c* minus *a*.
[f] Is *e* minus *d*.
[g] Is ratio of *f* to *a* (*f*/*a*).
[h] Is the percentage sum of land use/land covers that has not undergone changes between 1973 and 2007.

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